Product Introduction

# Development of Furniture Overturning Prevention Damper

UNE Masaya

## 1 Introduction

It is predicted that mega earthquakes such as the Tokyo inland earthquake or Nankai Trough earthquake will occur in the near future with a high probability. To be prepared for these earthquakes, many buildings in Japan have been made quake-proof. However, not many people have actually taken measures to prevent furniture overturning although they recognize the danger of furniture fall. People are reluctant to do so because they believe that such measures will "damage furniture and walls" or "just be ineffective".

According to a survey conducted by the Tokyo Fire Department [1)], it has been reported that 30 to 50 percent of the causes of injuries during large earthquakes in recent years are overturning, falling or movement of furniture. To prevent injuries and secondary damage related to furniture, it is very important to take appropriate furniture overturning/movement prevention measures.

General furniture overturning prevention devices can be roughly divided into two types. One is fixtures that secure furniture to the wall with L-shaped angle brackets, chains or belts. The other is tension rods, including pole-types that are installed between the top of furniture and the ceiling so as to prop the furniture. However, it is already known that these furniture overturning prevention devices are not very effective during a large earthquake of seismic intensity upper 6 or higher. Furthermore, when furniture is securely installed to the floor or wall with anchor bolts, the installation and removal will entail high costs.

So, KYB has launched an internal project to develop a furniture overturning prevention device by making use of its own expertise on damping systems, which is one of our core technologies. This article introduces the newly developed furniture overturning prevention damper.

## 2 Product Specifications

### 2.1 Overview of product

This product is designed so that two dampers are installed onto a single piece of furniture as shown in Photo 1. The dampers are set on the top panel of the furniture in positions near the back corners and installed in a slanting position between the ceiling and furniture so as to prevent the furniture from falling over. Normally the dampers are secured (installed) by the repulsion of their internal spring. If the furniture starts overturning during an earthquake, the dampers will shrink with a damping force exerted by its hydraulic system, preventing the furniture from overturning.

**Photo 1** Appearance of furniture overturning prevention damper

### 2.2 Furniture overturning prevention mechanism

This product is constructed so that the internal spring exerts a repulsion force alone during the stand-still and expansion phases and exerts both a repulsion force and hydraulic damping force during the contraction phase. How the product prevents furniture overturning is shown in Fig. 1.

During standstill, the dampers can secure the furniture with a relatively small repulsion force of around 60 N to 140 N, (the repulsion depends on how much the dampers installed are contracted). If the furniture starts overturning during a quake, the dampers will exert a damping force in the direction of contraction to prevent the furniture from falling over. When the furniture starts moving back to its original position, the dampers will quickly expand themselves with their repulsion to help the furniture move back.

Unlike the existing pole-type, this damper type tension rod has a pin-type rotary joint between the damper axis and pedestal. The pedestal can follow the inclination of the furniture and will never slide on the top surface of the furniture, contributing to the stable behavior of the product.

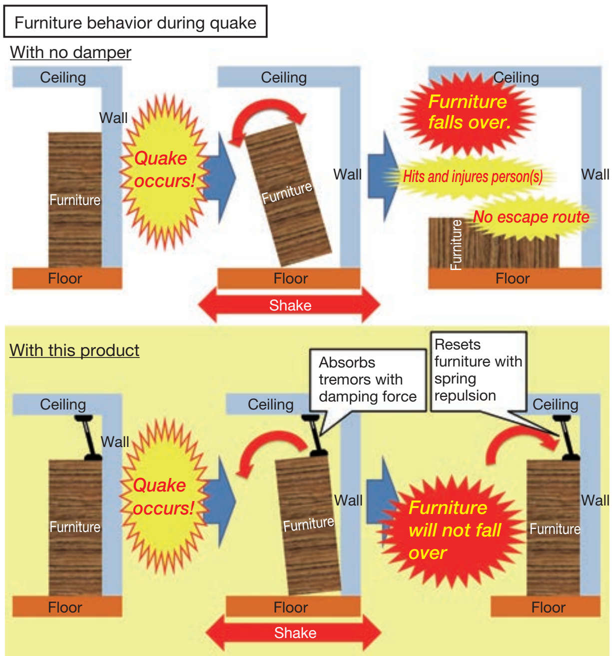


**Fig. 1** Furniture overturning prevention mechanism

### 2.3 Product components

The product components are shown in Fig. 2. Since the product is installed in a slanting position, the pedestal sheet uses a material with a high coefficient of friction. The damper can be made into contact with the angle control bracket to allow easy installation at an appropriate angle (about 17 degrees from the vertical position).

The damper is kept contracted with the contraction band to assist installation. When the damper is set between the top surface of the furniture and the ceiling board, the band can be cut to cause the damper to expand with its repulsion, thereby automatically installing the damper. (The contraction band should be removed after installation).

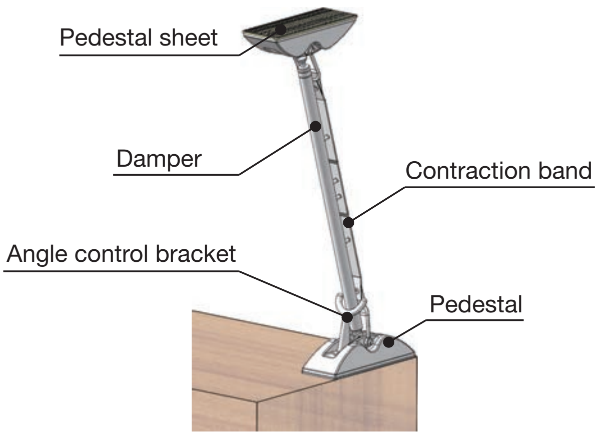


**Fig. 2** Parts structure

### 2.4 Effective setting condition

#### 2.4.1 Product lineup

Table 1 lists the product models for different height clearance ranges. The height clearance means the vertical clearance between the top surface of a piece of furniture and the ceiling (Fig. 3).

**Table 1** Product models for different height clearance ranges

| Model | Height clearance [cm] |
|---|---|
| PD16-43 | 43 – 50 |
| PD16-50 | 50 – 60 |
| PD16-60 | 60 – 74 |

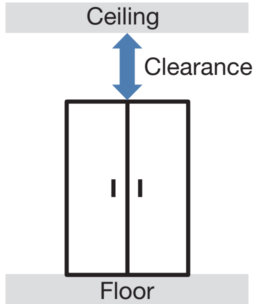


**Fig. 3** Height clearance

#### 2.4.2 Clearance range between furniture and wall

This product can only be used for furniture installed against a wall. The clearance between the furniture and the wall must be less than 3 cm, which is within the damper stroke (Fig. 4).

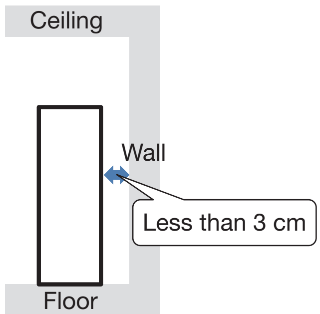


**Fig. 4** Clearance between furniture and wall

#### 2.4.3 Compatible ceilings

The product should be installed against a ceiling consisting of light gauge steel or wood ceiling joists and facing plates such as gypsum boards.

The target ceiling must have screws or nails fixing the facing plates (e.g., gypsum boards) either exposed or hidden behind any ceiling cloth, and must not be apparently dented when pressed with a finger at the position against which the damper pedestals are to be installed.

The product cannot be used for a lining board ceiling, system ceiling (with facing plates just placed on the frame), structurally weak ceiling, or non-horizontal ceiling.

#### 2.4.4 Compatible furniture

The product can be applied to furniture that has sufficient strength, has a horizontal top surface and is stably installed.

The product cannot be used for unstable furniture such as rollaway-types.

#### 2.4.5 Acceptable Floors

Wooden floors, tatami mats and any other types of floors are acceptable. For a slippery floor surface such as wood or tile, non-slip sheets for sideslip prevention provided with the product may be installed under the bottom of the furniture at both front corners to prevent a decrease in damping effect (Fig. 5).

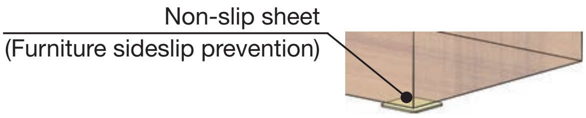


**Fig. 5** Non-slip sheet

### 2.5 Damper specifications

The dampers for this product are based on stay dampers generally used in automobile applications. The dampers are designed to be installed with their piston rod up (ceiling side) so that the damping force is applied only in the direction of contraction. Fig. 6 is a sketch of the internal structure of the dampers. While automobile stay dampers generally deliver repulsion with internal nitrogen gas, this product uses a metal spring instead of nitrogen gas. The reason is that the use of nitrogen gas would inevitably lead to lower gas pressure (lower repulsion) as service time goes by.

Unlike automobile stay dampers, these dampers have a cylindrical stopper on the piston rod to ensure that the piston has a sliding motion within the hydraulic fluid. With the stopper, the damping force will always be generated regardless of the position of the piston rod as long as it is within the stroke range.

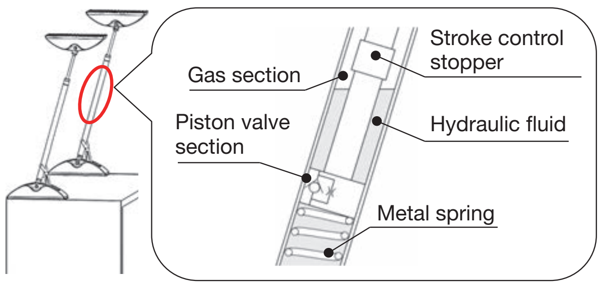


**Fig. 6** Internal structure of damper

To determine the damping force, the damper was subjected to a 3-axis shaking table test at several damping force levels. Then, a damping force value with which the highest rank of the official evaluation described in section 3.1 is expected to be obtained was selected.

## 3 Performance Evaluation

### 3.1 Official evaluation

#### 3.1.1 Official evaluation criteria

Performance evaluation of the product was carried out by an independent agency called General Incorporated Foundation (hereinafter "GIF") Japan Testing Center for Construction Materials according to "Overturning Prevention Device Performance Test and Evaluation Criteria"[2]. A piece of commonly used furniture (height 180cm, width 90cm, depth 40cm, weight 100kg or more) was used for the test. The shaking table was agitated with a seismic wave of intensity upper 6 observed by the Kobe Meteorological Observatory of the Japan Meteorological Agency during the Southern Hyogo Prefecture Earthquake (hereinafter "JMA Kobe wave") and the motion behavior of the furniture was measured and evaluated.

The evaluation result is expressed by the number of stars (☆). As the number of stars increases as in single (☆), double (☆☆) and triple (☆☆☆), the rank becomes higher. The top ranked dampers (with a triple star marking (☆☆☆)) are rated as "being able to minimize the tremor of the target specimen and prevent the overturning against a seismic motion equivalent to a seismic intensity upper 6".

Fig. 7 shows a graph of the rating criteria for performance evaluation. When the effective acceleration and maximum displacement of the top section of the furniture are plotted as shown in the figure, the red line, which is the straight line connecting the reference point of "effective acceleration 400 gal and maximum displacement 30mm" with the point of "effective acceleration 800 gal and maximum displacement 0mm", and the origin point can form a triangle. Measurements that fall within this triangle are rated as a triple star mark (☆☆☆).

The triple star ranked overturning prevention devices also must be visually identified to mostly stabilize the motion behavior of the specimen and have no deformations, damage or deviation.

#### 3.1.2 Official evaluation results

In the test, specimens were shaken three times in a row. Of the three results, the one with most unstable behavior was selected for evaluation. In this evaluation test, a piece of furniture with a mass of 122kg was used.

As a result, the product was within the top-ranked triple star (☆☆☆) area as shown in Fig. 7. The furniture slightly moved, but mostly remained in the original position after shaking.

The performance certificate for the product was applied for at the GIF Japan Testing Center for Construction Materials and is pending at this moment (as of January 2018).

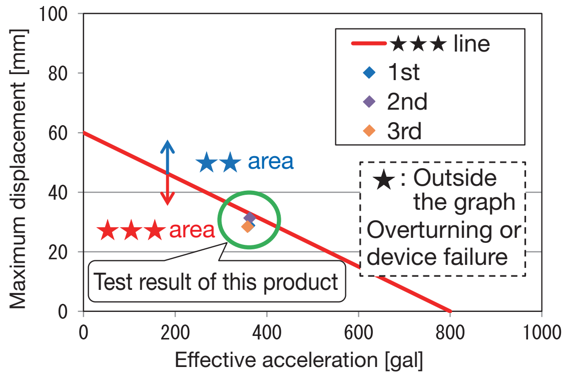


**Fig. 7** Performance evaluation criteria and test results

### 3.2 Tests on different shaking tables

#### 3.2.1 Evaluation using various seismic waves

Using several seismic waves of earthquakes that actually occurred (Table 2), the furniture overturning prevention performance was determined. Photo 2 shows how the 3-axis shaking table test was conducted.

**Photo 2** 3-axis shaking table test

On the shaking table, a room and a piece of furniture equivalent to those used in the official evaluation test in section 3.1 were installed. Non-slip sheets were placed between the floor and the bottom of the furniture (two locations at both front corners) to prevent sideslip.

**Table 2** Description of seismic waves

| Seismic wave | Intensity | Description |
|---|---|---|
| JMA Kobe | 6 upper | The seismic wave observed by Kobe Meteorological Observatory during the Southern Hyogo Prefecture Earthquake in 1995 |
| JMA Kobe NS 130% | Equivalent to 7 | The JMA Kobe wave multiplied by 1.3 only in the NS direction (front-back direction of the furniture) |
| K-NET Sendai | 6 lower | The seismic wave observed by Sendai City K-NET Note 1) during the Great East Japan Earthquake in 2011 |
| KiK-net Mashiki foreshock | 7 | The seismic wave observed by Mashiki-machi KiK-net Note 2) during the foreshock of the 2016 Kumamoto earthquakes |
| KiK-net Mashiki main shock | 7 | The seismic wave observed by Mashiki-machi KiK-net Note 2) during the main shock of the 2016 Kumamoto earthquakes |

Note 1) A nationwide network of strong-motion seismographs operated by National Research Institute for Earth Science and Disaster Resilience

Note 2) A network of strong-motion seismographs installed on the ground surface operated by National Research Institute for Earth Science and Disaster Resilience

In the test, the furniture did not fall over, even with a seismic wave equivalent to the seismic intensity 7 (JMA Kobe NS 130%) as shown in Table 3. For the test with the foreshock and main shock of the Kumamoto Earthquakes KiK-net Mashiki, the furniture rocked more heavily with the foreshock than with the main shock. This was probably because the seismic wave of the foreshock had a higher maximum vertical acceleration, thereby floating the furniture before being additionally applied with the longitudinal and lateral accelerations.

**Table 3** Test result by seismic wave

| Waveform | Result |
|---|---|
| JMA Kobe | Furniture rocked very little and remained stable. |
| JMA Kobe NS 130% | Furniture rocked very little and remained stable. |
| K-NET Sendai | Furniture rocked very little and remained stable. |
| KiK-net Mashiki foreshock | Furniture rocked to some extent, but did not fall over. |
| KiK-net Mashiki main shock | Furniture rocked slightly, but generally remained stable. |

### 3.2.2 Evaluation with simulated ceiling

The ceiling used for the official evaluation test in section 3.1 had sufficient strength for the testing condition. For this test, ceilings of general wooden houses and office buildings were simulated. Photo 3 shows the simulated general wooden house ceiling and Photo 4 the simulated

**Photo 3** Simulated general wooden house ceiling

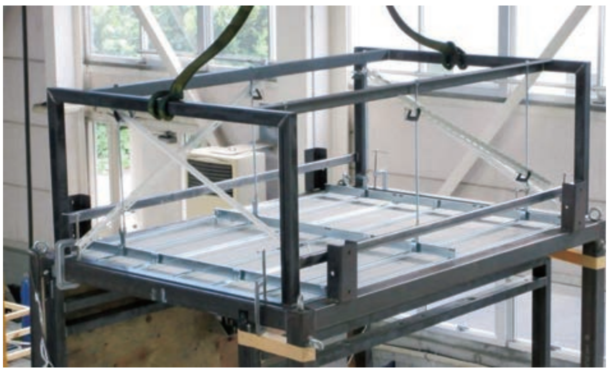

**Photo 4** Simulated office building ceiling

office building ceiling. The JMA Kobe wave was selected as the seismic wave to be applied. The furniture and the room components installed on the shaking table, except the ceiling, were equivalent to those used in the official evaluation test in section 3.1.

In the test, neither the simulated general wooden house ceiling nor the simulated office building ceiling was damaged as indicated in Table 4. As the ceiling deforms, the furniture rocked more largely but did not fall over. Recently constructed buildings probably have ceilings stronger than the simulated ceiling. Therefore, furniture in such buildings are likely to show even less effects.

**Table 4** Test result by ceiling type

| Ceiling | Result |
|---|---|
| Simulated for general wooden house | Furniture rocked to some extent, but did not fall over. The ceiling was not damaged. |
| Simulated for office building | Furniture rocked to some extent, but did not fall over. The ceiling was not damaged. |

### 3.3 Ceiling strength evaluation

The relationship between the damping force of the dampers during an earthquake and the ceiling strength was identified. As shown in Photo 5, a test jig simulating the pedestal of this product was used to apply a compressive load to the ceiling sample with steel furring, and the static breaking load was measured. The jig was pressed against the ceiling sample at the most disadvantageous position in terms of strength. The ceiling joist interval was selected using the examples of steel furring included in the "Gypsum Board Handbook" [3] issued by the general incorporated association (hereinafter GIA) Gypsum Board Association of Japan as a guide.

The static breaking load measurement was about 1300 N. Under the test condition for the official evaluation in section 3.1, the relevant damper showed a maximum damping force measurement of about 800 N. Therefore, the ceiling will not be damaged. However, dampers may behave differently depending on the furniture weight or seismic wave. It is also necessary to pay attention to ceiling damage or the gypsum board condition.

**Photo 5** Measurement of static breaking load on ceiling

## 4 Installation Status

Trial installation of the new product for monitoring purpose was launched in March 2016. 209 sets (418 pieces) of the dampers have been installed inside or outside KYB so far. In each installation location the product was installed by several individuals. It was found that most of them were able to install the product with no difficulty according to the instruction manual. Photo 6 shows the product installed at KYB Kumagaya Plant.

**Photo 6** Product installed at KYB Kumagaya Plant for monitoring purpose

## 5 In Closing

KYB successfully developed furniture overturning prevention dampers resistant to the seismic intensity 7 by making use of the company's proprietary damping technology, which is one of our core technologies. The product aimed at corporate clients started to be sold by KYB-YS Co., Ltd. in October 2017. Currently KYB-YS Co., Ltd. is promoting activities for order intake, cost reduction, performance improvement and lineup enhancement.

Finally, on this occasion, I would like to deeply thank all those who extended guidance and support in this development project.

**References**

1) Tokyo Fire Department: Furniture Tip Over, Fall and Movement Prevention Handbook, (2015 edition).
2) (GIF) Japan Testing Center for Construction Materials: Overturning Prevention Device Performance Test and Evaluation Criteria, (April 2008).
3) (GIA) Gypsum Board Association of Japan: Gypsum Board Handbook, (2016 edition).

## Author

**UNE Masaya**

Joined the company in 2009.
New Business Development Dept.,
Engineering Div.
(Stationed at Kumagaya Plant).
Engaged in development of new
business operations.